普通高等教育"十一五"规划教材
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机械工程专业英语

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前　言

专业英语是大学英语教学的重要组成部分，是促进学生完成从学习过渡到实际应用的有效途径。教育部于2007年颁布了《大学英语课程教学要求》，该文件中将大学英语的教学要求分为三个不同的层次——一般、较高和更高要求，并分别对这三个层次的英文文献阅读能力提出了不同的要求。强调大学英语课程要保证学生在整个大学期间的英语语言水平稳步提高，要能满足他们专业知识的发展，并提出应注重培养自主学习能力的教学思想和实践的转变。根据这个精神，编者编写本书，以帮助学生通过专业外语的学习能顺利阅读有关专业的原版教科书、参考书及其他参考资料，并满足高等院校机械类专业学生专业外语教学的需要和机械工程技术人员学习英语的要求。

全书共精选专业文章49篇，分为七部分，每部分各有侧重，读者可根据自己的专业领域选取不同部分进行阅读。主要内容包括：第一部分8篇，以金属材料及热处理方面的文章为主；第二部分包含了9篇有关机械零件方面的文章；第三部分的7篇文章则侧重于机械设计理论方面；第四部分的8篇文章为有关机械制造技术的基础知识及理论；第五部分是有关各种先进制造技术方面的6篇文章；第六部分10篇，侧重于机电控制技术；第七部分的11篇文章则属于扩展阅读，立足于反映出机械专业技术的现状和发展趋势，同时选取了部分与电力行业密切相关的文献材料。

本书内容新颖、取材精练、难度适中，所选内容涵盖了学生所学习过的专业知识，又有所拓展和延伸，从而既可提高读者的英语阅读水平，又能使读者了解学科前沿。

本书由华北电力大学杜必强担任主编。教材编写分工如下：河北农业大学王会强编写PART1，华北电力大学杨化动编写PART2、PART3及PART7的7.1、7.7～7.9，华北电力大学杜必强编写PART4、PART5及PART7的7.2～7.6，华北电力大学贾军编写PART6及PART7的7.10、7.11。

本书由中南大学周宏明副教授主审。审稿老师提出了很多宝贵的意见和建议，在此表示衷心的感谢。

由于编者水平所限，书中难免有不妥或错漏之处，恳请广大读者批评指正。

编　者
2010年2月

目　　录

Part 1 Mechanical Materials and Heat Treatment

1.1 Ferrous Metals and Their Use

It is known that ferrous metals are very important in the world, and have the greatest importance for industry. More than 90% by weight of the metallic materials used by human beings are ferrous alloys. Metals consisting of iron combined with some other elements are known as ferrous metals. All the other metals are called nonferrous metals. Ferrous metals include plain-carbon steels, alloy and tool steels, stainless steels, and cast irons. These groups of ferrous alloys have a wide variety of characteristics and applications.

Carbon steels are the most common steels used in industry. These eminently practical materials find applications from ball bearings to metal sheet formed into automobile bodies. The properties of these steels depend only on the percentage of carbon they contain. Low carbon steel containing from 0.02% to 0.25% carbon, and they are very soft and can be used for bolts and for machine parts that do not need strength. Medium carbon steel containing from 0.25% to 0.6% carbon which is a better grade and stronger than low carbon steel. High carbon steel containing from 0.6% to 2.11% carbon, these steel is sometimes called " tool steel ".They obtain high hardness by a quench and temper heat treatment. Their applications include cutting tools in machining operations, dies for die casting, forming dies, and other in which a combination of high strength hardness, toughness, or temperature resistance is needed.

Stainless steel require alloy additions to prevent damage from a corrosive atmosphere. Stainless steels are more resistant to rusting and staining than carbon and low alloy steels, due primarily to the presence of chromium addition. The amount of chromium is at least 12.7% and usually as high as 30%, which permits a thin protective surface layer of chromium oxide to form when steel is exposed to oxygen. There are four categories of stainless based on crystal structure and strengthen mechanism. They are the ferritic stainless steel, martensitic stainless steel, austenitic stainless steels, and precipitation hardening stainless steels.

The austenitic stainless steels have the austenite structure retained at room temperature. The austenite has the FCC structure and is stable above 910℃. This structure can occur at room temperature when it is stabilized by an appropriate alloy addition such as nickel. Without the high nickel content, the BCC structure is stable, as seen in the ferritic stainless steels. For many applications not requiring the high corrosion resistance of austenitic stainless steels, these lower alloy (and less expensive) ferritic stainless steels are quite serviceable. A rapid quench heat treatment discussed later allows the formation of a more complex body centered tetragonal crystal called martensite. This crystal structure yields high strength and low ductility. As a result, these martensitic stainless steels are excellent for applications such as cutlery and springs. Precipitation hardening is another heat treatment. Essentially, it involves producing a multiphase microstructure from a single phase one. The result is increased resistance to dislocation motion and, thereby, greater strength or hardness. Precipitation hardening stainless steels can be found in applications such as corrosion resistant structural members.

Cast irons are iron-carbon alloys that pass through the eutectic reaction during solidification and greater than 2.11% carbon. There are five important types of cast irons. White cast iron contains massive amounts of cementite and is a hard, brittle, unmachinable alloy. Gray cast iron contains small, interconnected graphite flakes that cause low strength and ductility. A significant silicon content (2% to 3%) promotes graphite precipitation rather than cementite. The sharp, pointed graphite flakes contribute to characteristic brittleness in gray iron. Malleable cast iron is produced by the heat treatment of white iron, causing cementites decomposed to irregular but rounded clumps of graphite. This graphite form permits good strength, ductility and toughness in the iron. Ductile or nodular cast iron contains spheroidal graphite particles. These spheroidal graphites are obtained during solidification by the addition of small amounts of magnesium to the molten iron. This resulting ductile iron derives its name from the improved mechanical properties compacted graphite cast iron contains vermicular graphite. They are also obtained during solidification by the addition of magnesium or rare earth elements. The structure and properties of compacted cast iron are intermediate between gray and ductile irons.

Words and Expressions

ferrous ['ferəs] *adj.*	铁的，含铁的
ferrous metals	黑色金属
nonferrous metals	有色金属
carbon steels	碳素钢
eminently ['eminəntli] *adv.*	杰出地
quench [kwentʃ] *vt.*	淬火
temper ['tempə] *vt.*	回火
hardness ['hɑːdnis] *n.*	硬度
toughness ['tʌfnis] *n.*	韧性，刚度
stainless steels	不锈钢
rust [rʌst] *vt.*	生锈
chromium ['krəumjəm] *n.*	铬
ferritic [fə'ritik] *n.*	铁素体
martensitic [ˌmɑːtin'zitik] *n.*	马氏体
austenitic [ˌɔstə'nitik] *n.*	奥氏体
precipitation hardening	沉淀硬化
FCC	面心立方
BCC	体心立方
ductility [dʌk'tiliti] *n.*	延展性
cutlery ['kʌtləri] *n.*	刀具
dislocation [ˌdislə'keiʃən] *n.*	位错
eutectic reaction	共晶反应
cast iron	铸铁
cementite [si'mentait] *n.*	渗碳体（Fe_3C）
malleable cast iron	可锻铸铁
nodular ['nɔdjulə] *adj.*	球状的
spheroidal graphite cast iron	球墨铸铁
magnesium[mæg'niːzjəm] *n.*	镁
molten ['məultən] *adj.*	熔化的，熔融的
vermicular graphites cast iron	蠕墨铸铁

1.2 Nonferrous Metals

Although ferrous alloys are used in the majority of metallic applications in current engineering designs, nonferrous alloys play a large and indispensable role in our technology. The most important nonferrous metals are copper, aluminum, lead, zinc, tin, but all these metals are used much less than ferrous metals, because the ferrous metals are much cheaper.

Aluminum is best known for low density and corrosion resistance. It has a density of 2.70 g/cm^3 or one third the density of steel. Although aluminum alloys have relatively low tensile properties compared to steel, their strength-to-weight ratio is excellent. Aluminum is often used when weight is an important factor, as in aircraft and automotive applications. On the other hand, aluminum often does not play an endurance limit in fatigue, so failure eventually occurs even at rather low stress. Because of its low melting point, aluminum does not perform well in the high temperatures. Finally, aluminum alloys have a low hardness, leading to poor wear resistance. Aluminum alloys can be subdivided into two groups, wrought aluminum and casting aluminum alloys. Wrought alloys are shaped by plastic deformation. They have compositions and microstructures significantly different from casting alloys. It reflects the different requirements of manufacturing process. Within wrought alloys group we can divide the alloys into two subgroups—heat treatable and nonheat treatable alloys. Heat treatable alloys have a high hardness, whereas nonheat treatable alloys are hardend by solid solution strengthing.

Copper alloys possess a number of superior properties. Their excellent electrical conductivity makes copper alloys the leading material for electrical wiring. Their excellent thermal conductivity leads to applications for radiators and heat exchangers. Superior corrosion resistance is exhibited in marine and other corrosive environments. The FCC structure contributes to their generally high ductility and formability. Copper alloys are also unique in that they may be selected to produce an appropriate decorative color. Pure copper is red. However zinc additions produce yellow color and nickel produce a silver color. The copper can take advantage of all of the strengthening mechanism. So there are a myriad of copper-base alloys. The copper-zinc alloys are known as brass. Manganese bronze is a particularly high-strength alloy containing manganese as well as zinc for solid solution strengthening. A copper-nickel-zinc ternary alloy is called nickel silver. Although it does have a silver color, it really has no silver present. The formability of these alloys approaches that of copper-zinc alloys.

Magnesium alloys have even lower density than aluminum, and as a result, appear in numerous structural applications such as aerospace designs, high speed machinery, and transportation and materials handling equipment. However, magnesium has a low modulus of elasticity and poor resistance to fatigue, creep, and wear. Magnesium also poses a hazard during casting and machining, since it combines easily with oxygen and burns. Finally, the response of magnesium to strengthening mechanisms is relatively poor. In magnesium alloys, strengthening is achieved by solid solution strengthening, strain strengthening; grain size control, dispersion strengthening, and age hardening. As in aluminum alloys, the solubility of the alloying elements in magnesium is rather low, so the degree of solid solution strengthening is limited.

Nickle alloys are used for corrosion protection and for high temperature resistance. It takes advantages of its high melting point and high strength. The lattice of nickle is FCC structures and has good formability. Nickle alloys have much in common with copper alloys. We have already used the Ni-Cu system as the classic example of complete solid solubility. When copper is added to nickle, the maximum strength is obtained near 60% Ni. A number of alloys, called Monels, contain approximately this composition. They are used in salt water and at a relative high temperature for their strength and corrosion resistance. Nickle is harder than copper, but monel is harder than nickle. Nickle exhibits excellent corrosion resistance and high temperature strength. Some of the monels contain small amounts of aluminum and titanium. These alloys show an age hardening. Superalloys contain large amounts of alloying elements. These elements can produce a combination of high strength at elevated temperature, resistance to deformation at temperatures up to 1000℃, and resistance to corrosion. There are three categories of superalloys. They are nickle base alloy, iron-nickle base alloy, and cobalt base alloy. Typical use includes vanes for turbine and jet engines, heat exchangers, chemical reaction vessel components, and heat-treating equipment.

Different metals are produced in different ways, but almost all the metals are found in the form of metal ore (iron ore, copper ore, etc.). The ore is a mineral consisting of a metal combined with some impurities. In order to produce a metal from some metal ore, we must separate these impurities from the metal that is done by metallurgy.

Words and Expressions

copper ['kɔpə] *n.*	铜
aluminum [ˌæljuː'minjəm] *n.*	铝
lead [liːd] *n.*	铅
zinc [ziŋk] *n.*	锌
tin [tin] *n.*	锡
density ['densiti] *n.*	密度
tensile ['tensail] *adj.*	张紧的，拉紧的
fatigue [fə'tiːg] *n.*	疲劳
failure ['feiljə] *n.*	失效
wrought aluminum alloy	形变铝合金
casting aluminum alloy	铸造铝合金
heat treatable	可热处理强化
solid solution strengthing	固溶时效强化
brass [brɑːs] *n.*	黄铜
manganese bronze	锰青铜
modulus ['mɔdjuləs] *n.*	模（数，量）
elasticity [ilæs'tisiti] *n.*	弹性
strain strengthening	加工硬化
grain size control	细晶强化
dispersion strengthening	弥散强化
age hardening	时效强化
lattice ['lætis] *n.*	晶格

Monel [məu'nel] *n.* 蒙乃尔合金
nickle base alloy 以镍为基的合金
cobalt [kə'bɔːlt] *n.* 钴
vane [vein] *n.* 叶片
turbine ['təːbin] *n.* 汽轮机，涡轮
vessel ['vesəl] *n.* 容器
ore [ɔː(r)] *n.* 矿石
impurity [im'pjuəriti] *n.* 杂质
metallurgy [mi'tælədʒi] *n.* 冶金术

1.3 Ceramics and Other Materials

A ceramic is an inorganic, non-metallic solid prepared by the action of heat and subsequent cooling. Ceramic materials may have a crystalline or partly crystalline structure, or may be amorphous (e.g., a glass). Because most common ceramics are crystalline, the definition of ceramic is often restricted to inorganic crystalline materials, as opposed to the non-crystalline glasses.

Ceramics have been traditionally known as hard materials that can withstand harsh environments and high temperature. These attributes have lead to their use in applications such as cutting tools and turbine coatings. However, ceramics are also rich in electrical and magnetic properties, which have lead to their use as insulators, dielectrics, superconductors, magnets, electrodes, and electrolytes.

Ceramics are used in the manufacture of knives. The blade of a ceramic knife will stay sharp for much longer than that of a steel knife, although it is more brittle and can be snapped by dropping it on a hard surface. Ceramics such as alumina and boron carbide have been used in ballistic armored vests to repel large-calibre rifle fire. Such plates are known commonly as Small Arms Protective Inserts (SAPI). Similar material is used to protect cockpits of some military airplanes, because of the low weight of the material. Ceramic balls can be used to replace steel in ball bearings. Their higher hardness means that they are much less susceptible to wear and can offer more than triple lifetimes. They also deform less under load meaning they have less contact with the bearing retainer walls and can roll faster. In very high speed applications, heat from friction during rolling can cause problems for metal bearings; problems which are reduced by the use of ceramics. Ceramics are also more chemically resistant and can be used in wet environments where steel bearings would rust. The two major drawbacks to using ceramics is a significantly higher cost, and susceptibility to damage under shock loads. In many cases their electrically insulating properties may also be valuable in bearings.

In the early 1980s, Toyota researched production of an adiabatic ceramic engine which can run at a temperature of over 6000°F (3300°C). Ceramic engines do not require a cooling system and hence allow a major weight reduction and therefore greater fuel efficiency. Fuel efficiency of the engine is also higher at high temperature. In a conventional metallic engine, much of the energy released from the fuel must be dissipated as waste heat in order to prevent a meltdown of the metallic parts. Despite all of these desirable properties, such engines are not in production because the manufacturing of ceramic parts in the requisite precision and durability is difficult. Imperfection in the ceramic leads to cracks, which can lead to potentially dangerous equipment failure. Such engines are possible in laboratory settings, but mass-production is not feasible with current technology.

Work is being done in developing ceramic parts for gas turbine engines. Currently, even blades made of advanced metal alloys used in the engines' hot section require cooling and careful limiting of operating temperatures. Turbine engines made with ceramics could operate more efficiently, giving aircraft greater range and payload for a set amount of fuel.

Recently, there have been advances in ceramics which include bio-ceramics, such as dental implants and synthetic bones. Hydroxyapatite, the natural mineral component of bone, has been made synthetically from a number of biological and chemical sources and can be formed into ceramic materials. Orthopedic implants made from these materials bond readily to bone and other tissues in the body without rejection or inflammatory reactions. Ultimately these ceramic materials may be used as bone replacements or with the incorporation of protein collagens, synthetic bones.

High-tech ceramic is used in watchmaking for producing watch cases. The material is valued by watchmakers for its light weight, scratch-resistance, durability and smooth touch. IWC is one of the brands that initiated the use of ceramic in watchmaking. The case of the IWC 2007 Top Gun edition of the Pilot's Watch Double chronograph is crafted in high-tech black ceramic.

Plastic is the general common term for a wide range of synthetic or semisynthetic organic amorphous solid materials suitable for the manufacture of industrial products. Plastics are typically polymers of high molecular weight, and may contain other substances to improve performance and reduce costs.

The word derives from the Greek *πλαστικός* (plastikos) meaning fit for molding, and *πλαστός* (plastos) meaning molded. It refers to their malleability, or plasticity during manufacture, that allows them to be cast, pressed, or extruded into an enormous variety of shapes—such as films, fibers, plates, tubes, bottles, boxes, and much more.

The common word *plastic* should not be confused with the technical adjective *plastic*, which is applied to any material which undergoes a permanent change of shape (plastic deformation) when strained beyond a certain point. Aluminum, for instance, is plastic in this sense, but not a plastic in the common sense; while some plastics, in their finished forms, will break before deforming and therefore are not plastic in the technical sense.

There is no single plastics material which is suitable for all applications. It is important that the most suitable plastics should be chosen, and if necessary adapted, for each particular requirement. It is also important that the properties of the plastics material chosen should be exploited to the best advantage.

As important materials, the polymers are available in a wide variety of commercial forms: fibers, thin films and sheets, foams and in bulk. Polymer properties are broadly divided into several classes based on the scale at which the property is defined as well as upon its physical basis. The most basic property of a polymer is the identity of its constituent monomers. A second set of properties, known as microstructure, essentially describe the arrangement of these monomers within the polymer at the scale of a single chain. These basic structural properties play a major role in determining bulk physical properties of the polymer, which describe how the polymer behaves as a continuous macroscopic material. Chemical properties, at the nano-scale, describe how the chains interact through various physical forces. At the macro-scale, they describe how the bulk polymer interacts with other chemicals and solvents.

The bulk properties of a polymer are those most often of end-use interest. These are the properties that dictate how the polymer actually behaves on a macroscopic scale.

The tensile strength of a material quantifies how much stress the material will endure before failing. This is very important in applications that rely upon a polymer's physical strength or durability. For example, a rubber band with a higher tensile strength will hold a greater weight before snapping. In general, tensile strength increases with polymer chain length and crosslinking of polymer chains.

Young's Modulus quantifies the elasticity of the polymer. It is defined, for small strains, as the ratio of rate of change of stress to strain. Like tensile strength, this is highly relevant in polymer applications involving the physical properties of polymers, such as rubber bands. The modulus is strongly dependent on temperature.

Words and Expressions

ceramics [si'ræmiks] *n.* 陶瓷
inorganic [ˌinɔː'gænik] *adj.* 无机的
crystalline ['kristəlain] *adj.* 水晶的；晶态的
amorphous [ə'mɔːfəs] *adj.* 非晶态的
insulator ['insjuleitə] *n.* 绝缘器
dielectric [ˌdaii'lektrik] *n.* 电介质，绝缘体
superconductor [ˌsjuːpəkən'dʌktə] *n.* 超导材料
electrolyte [i'lektrəulait] *n.* 电解质
blade [bleid] *n.* 刀口；刀刃
snap [snæp] *vt.&vi.* 突然断裂
alumina [ə'ljuːminə] *n.* 氧化铝
boron carbide 碳化硼
ballistic [bə'listik] *adj.* 发射的
armored ['ɑːməd] *adj.* 装甲的
repel [ri'pel] *vt.* 抵制
small-arms 轻武器
inserts *n.* 填充物
cockpit ['kɔkpit] *n.* 飞机驾驶室
susceptible [sə'septəbl] *adj.* 能经受的
adiabatic [ˌædiə'bætik] *adj.* 隔热的
imperfection [ˌimpə'fekʃən] *n.* 缺点
bio-ceramics 生物陶瓷
synthetic [sin'θetik] *adj.* 合成的，造的
hydroxyapatite [haiˌdrɔksi'æpətait] *n.* 羟磷灰石
synthetically *adv.* 综合地；合成地
orthopedic [ˌɔːθəu'piːdik] *adj.* 整形外科的
tissues ['tisjuː] *n.* 组织
scratch-resistance 抗划伤性
IWC 万国表公司
chronograph ['krɔnəgrɑːf] *n.* 计时表
semisynthetic ['semisin'θetik] *adj.* 半合成的
polymer ['pɔlimə] *n.* 聚合物

malleability [ˌmæliə'biliti] *n.*	有延展性，柔顺性	bulk physical properties	整体物理特性
foam [fəum] *n.*	泡沫	end-use	最终用途
monomer ['mɔnəmə] *n.*	单体	Young's Modulus	杨氏模量

1.4 Castings

In metalworking, casting involves pouring a liquid metal into a mold, which contains a hollow cavity of the desired shape, and then is allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting is most often used for making complex shapes that would be difficult or uneconomical to make by other methods.

The casting process is subdivided into two main categories: expendable and non-expendable casting. It is further broken down by the mold material, such as sand or metal, and pouring method, such as gravity, vacuum, or low pressure.

Casting is a solidification process, which means the solidification phenomenon controls most of the properties of the casting. Moreover, most of the casting defects occur during solidification, such as gas porosity and solidification shrinkage.

Solidification occurs in two steps, nucleation and crystal growth. In the nucleation stage solid particles form within the liquid. When these particles form their internal energy is lower than the surrounded liquid, which creates an energy interface between the two. The formation of the surface at this interface requires energy, so as nucleation occurs the material actually undercools, that is it cools below its freezing temperature, because of the extra energy required to form the interface surfaces. It then recalescences, or heats back up to its freezing temperature, for the crystal growth stage. Note that nucleation occurs on a pre-existing solid surface, because not as much energy is required for a partial interface surface, as is for a complete spherical interface surface. This can be advantageous because fine-grained castings possess better properties than coarse-grained castings. A fine grain structure can be induced by grain refinement or inoculation, which is the process of adding impurities to induce nucleation.

All of the nucleations represent a crystal, which grows as the heat of fusion is extracted from the liquid until there is no liquid left. The direction, rate, and type of growth can be controlled to maximize the properties of the casting. Directional solidification is when the material solidifies at one end and proceeds to solidify to the other end; this is the most ideal type of grain growth because it allows liquid material to compensate for shrinkage.

Cooling curves are important in controlling the quality of a casting（see Fig.1-1）. The most important part of the cooling curve is the cooling rate which affects the microstructure and properties. Generally speaking, an area of the casting which is cooled quickly will have a fine grain structure and an area which cools slowly will have a coarse grain structure.

Below is an example cooling curve of a pure metal or eutectic alloy, with defining terminology.

Note that before the thermal arrest the material is a liquid and after it the material is a solid; during the thermal arrest the material is converting from a liquid to a solid. Also, note that the greater the superheat the more time there is for the liquid material to flow into intricate details.

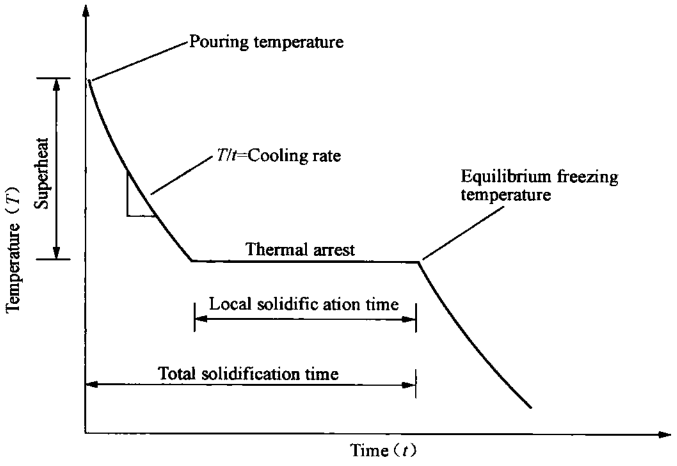

Fig.1-1 Cooling curve of a pure metal or eutectic alloy

The cooling rate is largely controlled by the mold material. When the liquid material is poured into the mold, the cooling begins. This happens because the heat within the molten metal flows into the relatively cooler parts of the mold. Molding materials transfer heat from the casting into the mold at different rates. For example, some molds made of plaster may transfer heat very slowly, while steel would transfer the heat quickly. Where heat should be removed quickly, the engineer will plan the mold to include special heat sinks to the mold, called chills. Fins may also be designed on a casting to extract heat, which are later removed in the cleaning (also called fettling) process. Both methods may be used at local spots in a mold where the heat will be extracted quickly. Where heat should be removed slowly, a riser or some padding may be added to a casting.

The gating system serves many purposes, the most important being conveying the liquid material to the mold, but also controlling shrinkage, the speed of the liquid, turbulence, and trapping dross. The gates are usually attached to the thickest part of the casting to assist in controlling shrinkage. In especially large castings multiple gates or runners may be required to introduce metal to more than one point in the mold cavity. The speed of the material is important because if the material is traveling too slow it can cool before completely filling, leading to misruns and cold shuts. If the material is moving too fast then the liquid material can erode the mold and contaminate the final casting. The shape and length of the gating system can also control how quickly the material cools; short round or square channels minimize heat loss.

The gating system may be designed to minimize turbulence, depending on the material being cast. For example, steel, cast iron, and most copper alloys are turbulent insensitive, but aluminium and magnesium alloys are turbulent sensitive. The turbulent insensitive materials usually have a short and open gating system to fill the mold as quickly as possible. However, for turbulent sensitive materials short sprues are used to minimize the distance the material must fall when entering the mold. Rectangular pouring cups and tapered sprues are used to prevent the formation of a vortex as the material flows into the mold; these vortexes tend to suck gas and oxides into the mold. A large sprue well is used to dissipate the kinetic energy of the liquid material as it falls down the sprue, decreasing turbulence. The choke, which is the smallest cross-sectional area in the gating system used to control flow, can be placed near the sprue well to slow down and smooth out the flow. Note that on some molds the choke is still placed on the gates to make separation of the part easier, but induces extreme turbulence. The gates are usually attached to the bottom of the casting to minimize turbulence and splashing.

The gating system may also be designed to trap dross. One method is to take advantage of the fact that some dross has a lower density than the base material so it floats to the top of the gating system. Therefore long flat runners with gates that exit from the bottom of the runners can trap dross in the runners; note that long flat runners will cool the material more rapidly than round or square runners. For materials where the dross is a similar density to the base material, such as aluminium, runner extensions and runner wells can be advantageous. These take advantage of the fact that the dross is usually located at the beginning of the pour, therefore the runner is extended past the last gates and the contaminates are contained in the wells. Screens or filters may also be used to trap contaminates.

It is important to keep the size of the gating system small, because it all must be cut from the casting and remelted to be reused. The efficiency, or yield, of a casting system can be calculated by dividing the weight of the casting by the weight of the metal poured. Therefore, the higher the number the more efficient the gating system/risers.

There are a number of problems that can be encountered during the casting process. One is metal contamination which is called dross, if it is a solid, or slag, if is a liquid. There are a number of ways to minimize this contamination. In order to reduce oxide formation the metal can be melted with a flux, in a vacuum, or in an inert atmosphere. Other ingredients can be added to the mixture to cause the dross to float to the top where it can be skimmed off before the metal is poured into the mold. If this is not practical, then a special ladle that pours the metal from the bottom can be used. The gating system can be designed to trap any dross that might enter the mold, or a ceramic filter can be installed. If some of the dross or slag gets folded into the molten metal then its known as an entrainment defect.

Another problem that can occur is known as gas porosity, which is the formation of bubbles within the casting after it has cooled. This occurs because most liquid materials can hold a large amount of dissolved gas, but the solid form of the same material cannot, so the gas forms bubbles within the material as it cools. To prevent gas porosity the material may be melted in a vacuum, in an environment of low-solubility gases, or under a flux that prevents contact with the air. Also, the superheat temperatures can be kept low to minimize gas solubility. Turbulence in the liquid materials as it enters the mold can induce a lot of gases, so the mold is often streamlined to minimize such turbulence. Other methods include vacuum degassing, gas flushing, or precipitation. Precipitation involves reacting the gas with another element to form a compound that will form a dross that floats to the top. For instance, oxygen can be removed from copper by adding phosphorus, or aluminium or silicon can be added to steel to remove oxygen.

Two more closely related problems are misruns and cold shuts, both involve the material freezing before it completely fills the mold cavity. The castability and fluidity of the material can be large factors with these problems. Fluidity affects the minimum section thickness that can be cast, the maximum length of a thin section, how fine of a detail that can be cast, and the accuracy of filling mold extremities. There are various ways of measuring the fluidity of a material, although it usually involves using a standard mold shape and measuring how far the material flows. Fluidity is affected by the composition of the material, freezing temperature or range, surface tension of oxide films, and, most importantly, the pouring temperature. The higher the pouring temperature the greater the fluidity, however excessive temperatures can be detrimental. High pouring temperatures can lead to a reaction between the material and the mold.

Words and Expressions

casting ['kɑːstiŋ] *n.* 铸造
metalworking ['metl,wəːkiŋ] *n.* 金属加工术
mold [məuld] *n.* 模型
cavity ['kæviti] *n.* 腔；洞
gas porosity 气孔
nucleation [,njuːkli'eiʃən] *n.* 成核
undercool ['ʌndə'kuːl] *n.* 过度冷却（过冷度）
freezing temperature 凝固温度
recalescence [,rikə'lesns] *n.* 复辉，再炽热
pre-existing 先存在
fine-grained 细晶
coarse-grained 粗晶
eutectic [juː'tektik] *n.* 共晶
terminology [,təːmi'nɔlədʒi] *n.* 术语
thermal arrest 平衡温度
intricate details 模制品
plaster ['plɑːstə] *n.* 石膏
fettling ['fetliŋ] *n.* 涂炉材料（如硅石）
padding ['pædiŋ] *n.* 衬料或衬垫
gating system 浇注系统
turbulence ['tɜːbjuləns] *n.* 波动
dross [drɔs] *n.* 渣滓，无用之物
misrun ['misrʌn] *v.* 未浇注满
contaminate [kən'tæmineit] *vt.* 污染，弄脏
turbulent insensitive 不好的波动性
sprue [spruː] *n.* 注入口
rectangular [rek'tæŋgjulə] *n.* 长方形
tapered *adj.* 锥形的
vortex ['vɔːteks] *n.* 涡流，旋涡
dissipate ['disipeit] *vt. &vi.* 驱散，使消失
choke [tʃəuk] *n.* 阻风门，阀门
splashing 喷洒，泼洒
runner ['rʌnə] *n.* 滑道
riser ['raizə] *n.* 冒口

slag [slæg] *n.*	矿渣
flux [flʌks] *n.*	助熔剂
inert atmosphere	惰性气氛
ingredients [in'griːdjənt] *n.*	配料
ladle ['leidl] *n.*	钢包
entrainment [in'treinmənt] *n.*	夹杂
degassing [diː'gæsiŋ] *n.*	排气
gas flushing	真空密封
precipitation [priˌsipi'teiʃən] *n.*	沉淀析出
phosphorus ['fɔsfərəs] *n.*	磷
cold shuts	铸件中的冷隔或裂纹
castability	铸造性
detrimental [ˌdetri'mentl] *adj.*	有害的，不利的

1.5 Forging

Forging is the term for shaping metal by using localized compressive forces. Cold forging is done at room temperature or near room temperature. Hot forging is done at a high temperature, which makes metal easier to shape and less likely to fracture. Warm forging is done at intermediate temperature between room temperature and hot forging temperatures. Forged parts can range in weight from less than a kilogram to 170 metric tons. Forged parts usually require further processing to achieve a finished part.

Forging results in metal that is stronger than cast or machined metal parts. This stems from the grain flow caused through forging. As the metal is pounded the grains deform to follow the shape of the part, thus the grains are unbroken throughout the part. Some modern parts take advantage of this for a high strength-to-weight ratio.

Many metals are forged cold, but iron and its alloys are almost always forged hot. This is for two reasons: first, if work hardening were allowed to progress, hard materials such as iron and steel would become extremely difficult to work with; secondly, steel can be strengthened by other means than cold-working, thus it is more economical to hot forge and then heat treat. Alloys that are amenable to precipitation hardening, such as most alloys of aluminium and titanium, can also be hot forged then hardened. Other materials must be strengthened by the forging process itself.

There are many different kinds of forging processes available, however they can be grouped into three main classes:

Drawn out: length increases, cross-section decreases.

Upset: Length decreases, cross-section increases.

Squeezed in closed compression dies: produces multidirectional flow.

Upset forging increases the diameter of the workpiece by compressing its length. Based on number of pieces produced this is the most widely used forging process. A few examples of common parts produced using the upset forging process are engine valves, couplings, bolts, screws, and other fasteners.

Upset forging is usually done in special high speed machines called crank presses, but upsetting can also be done in a vertical crank press or a hydraulic press. The machines are usually set up to work in the horizontal plane, to facilitate the quick exchange of workpieces